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**Shimizu**

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(54) **IMAGE PROCESSING DEVICE AND IMAGE PROCESSING METHOD FOR CAMERA CALIBRATION**

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**G06T 7/00** (2006.01)  
**G06K 9/00** (2006.01)

(52) **U.S. Cl.**  
CPC ..... **G06T 7/0042** (2013.01); **G06K 9/00798** (2013.01); **G06T 7/0018** (2013.01); **G06T 2207/10016** (2013.01); **G06T 2207/30252** (2013.01); **G06T 2207/30256** (2013.01)

(58) **Field of Classification Search**  
CPC ..... G06K 9/00798; G06T 7/0042  
USPC ..... 348/36  
See application file for complete search history.

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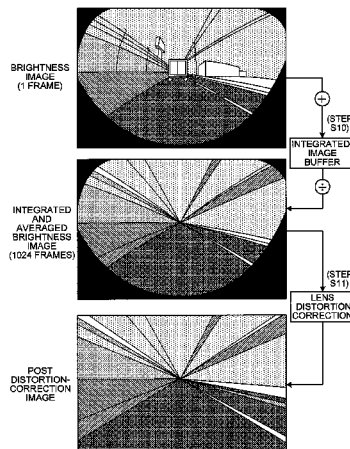
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(57) **ABSTRACT**

In a calibration device, an image-integration averaging processing unit integrates/averages an image so as to generate an integrated and averaged image, and an edge extracting unit extracts the edges from the integrated and averaged image. A vanishing-point extracting unit calculates vanishing lines by using the edges and identifies the coordinates of the intersection point of the vanishing lines as the coordinates of the vanishing point. An error determining unit compares the coordinates of the current vanishing point with the coordinates of the previous vanishing point so as to determine whether a parameter of the camera needs correcting. In accordance with the result of the determination, a correction processing unit corrects a parameter of the camera.

**9 Claims, 13 Drawing Sheets**



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			* cited by examiner	

FIG.1

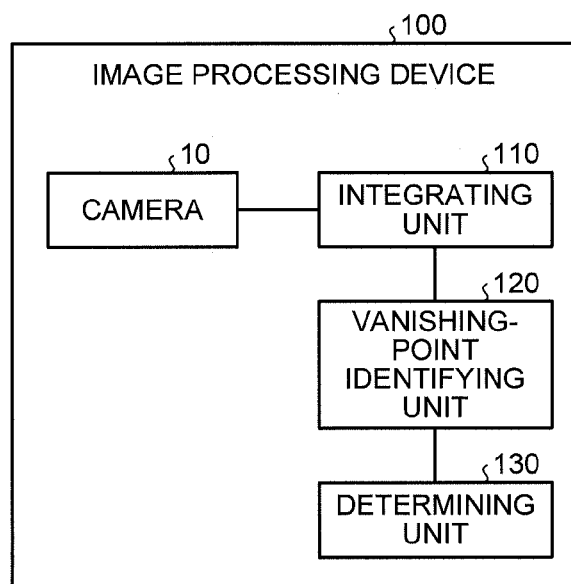


FIG.2

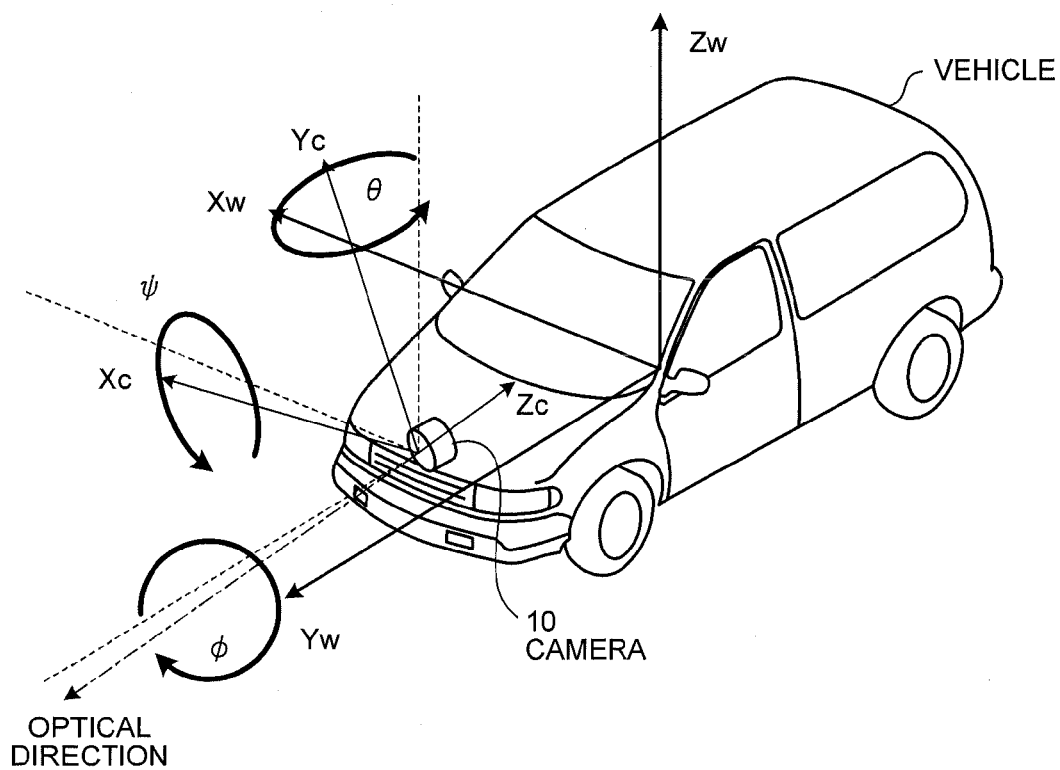


FIG.3

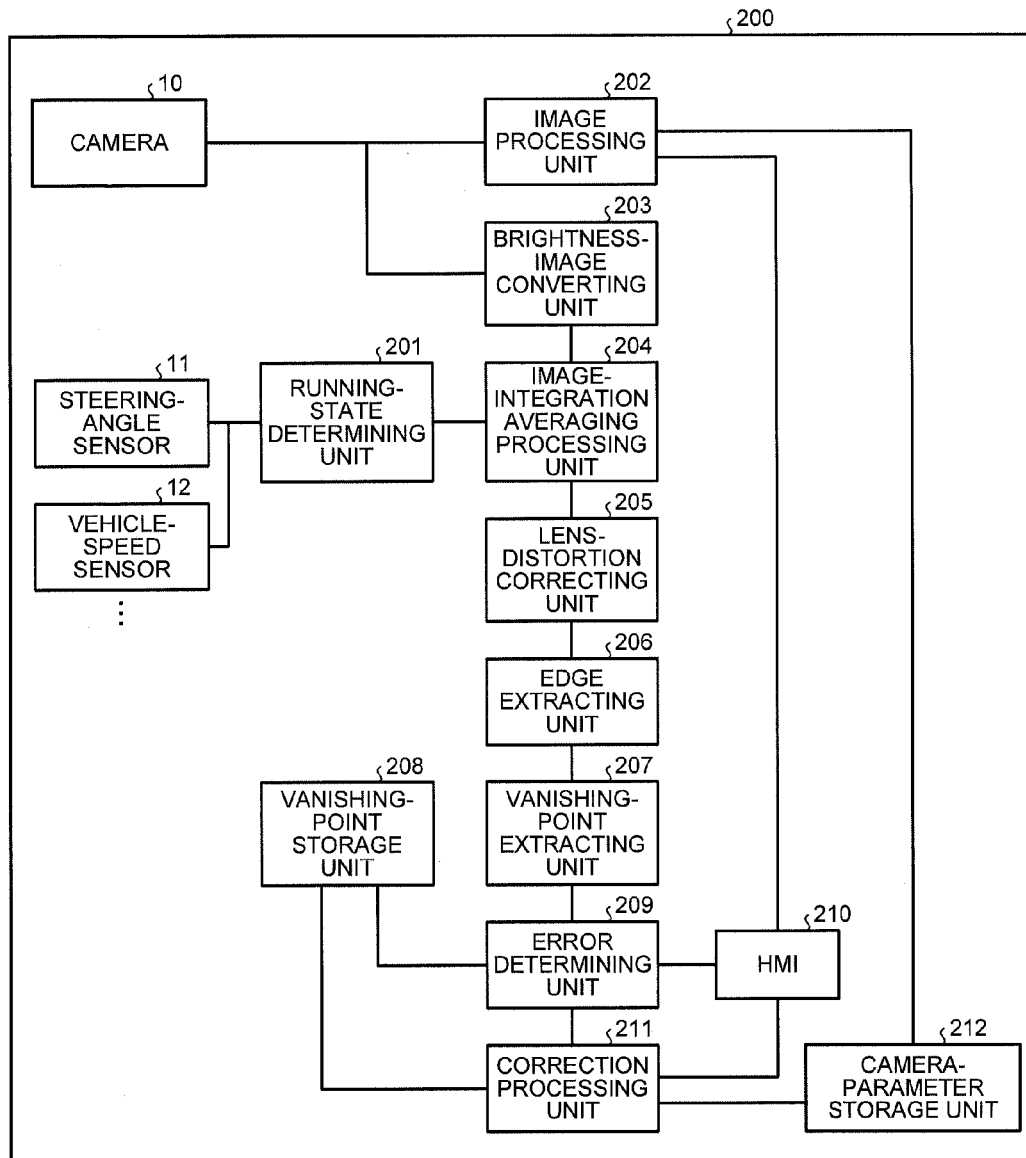


FIG. 4

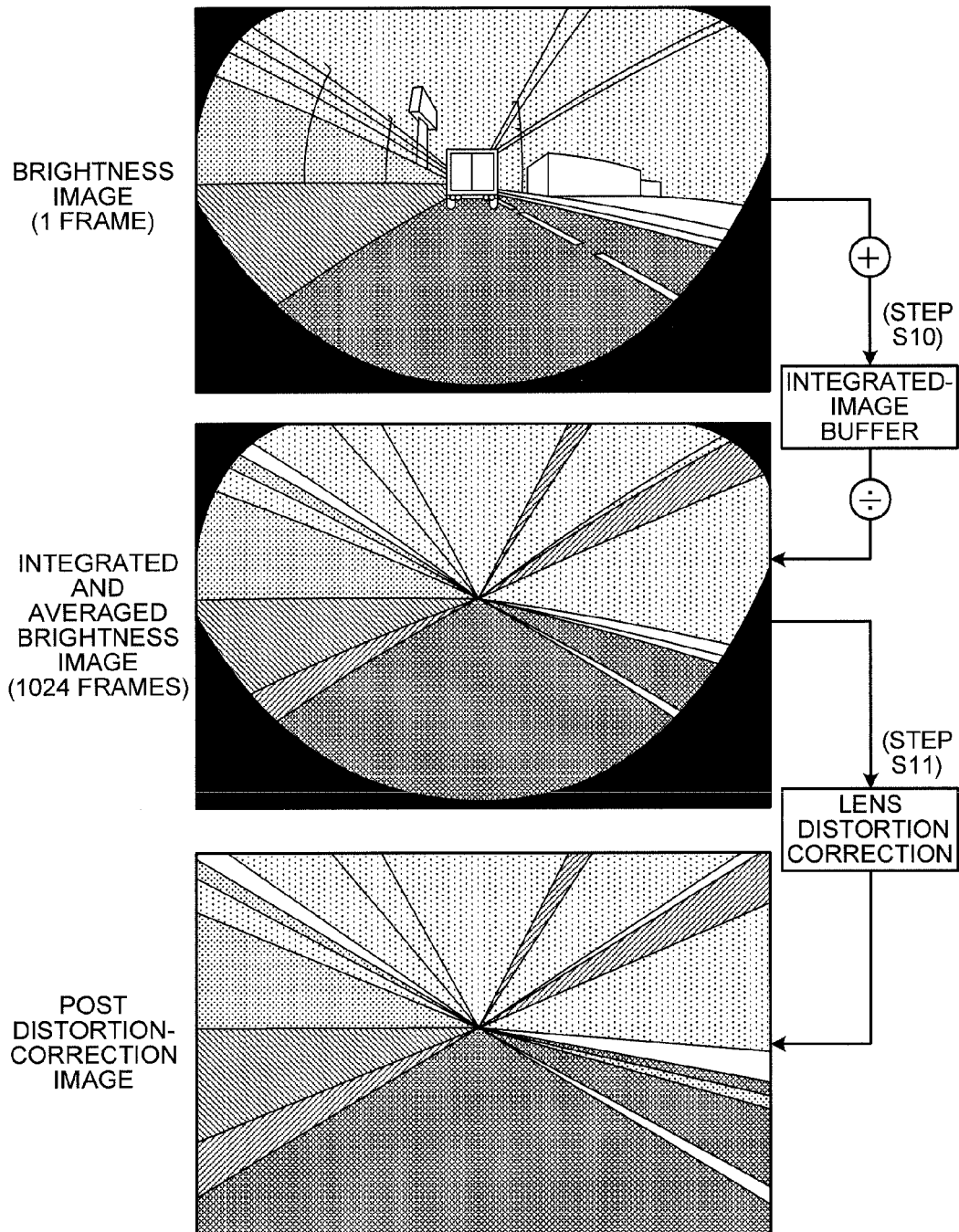


FIG.5

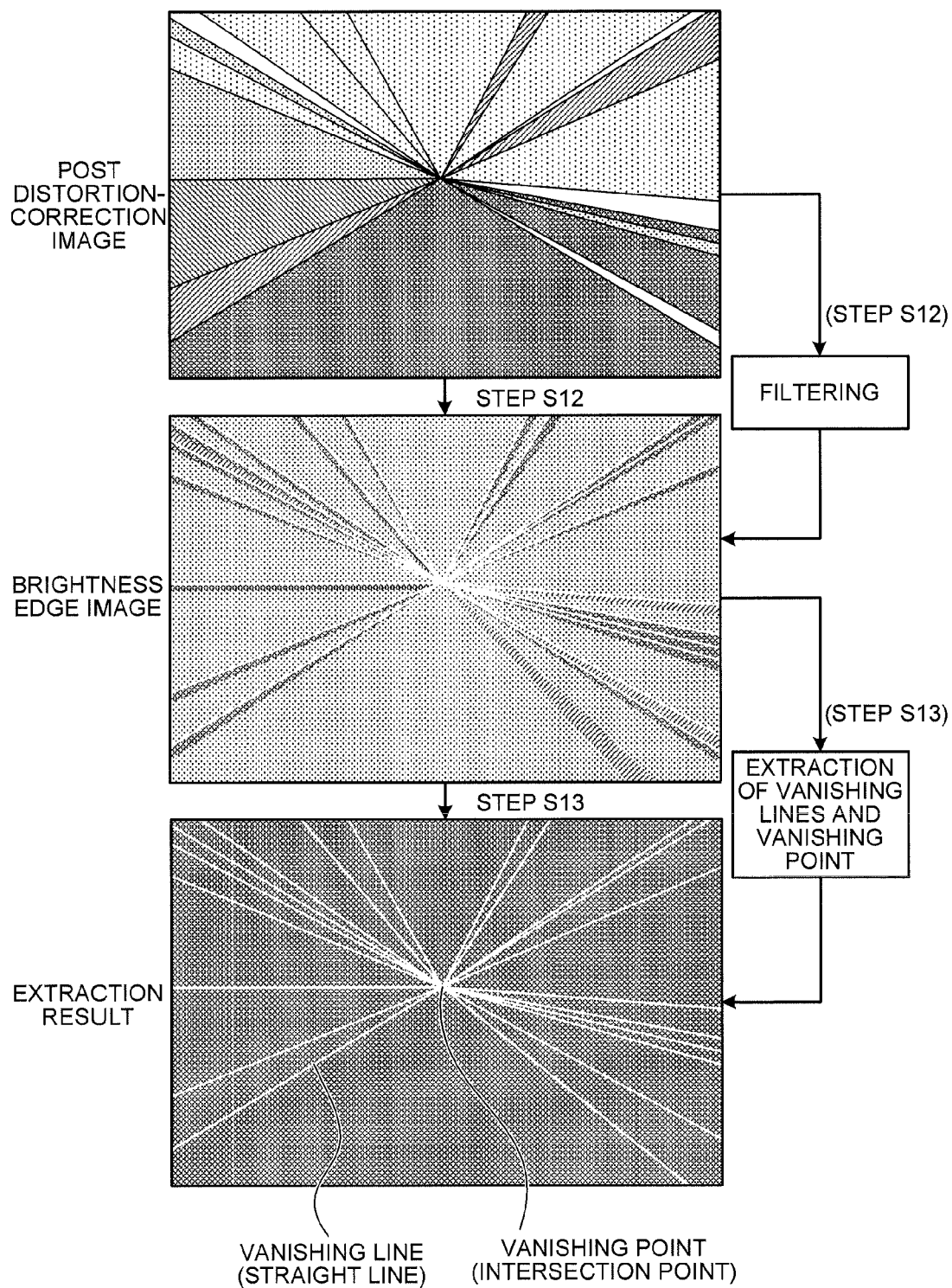


FIG.6

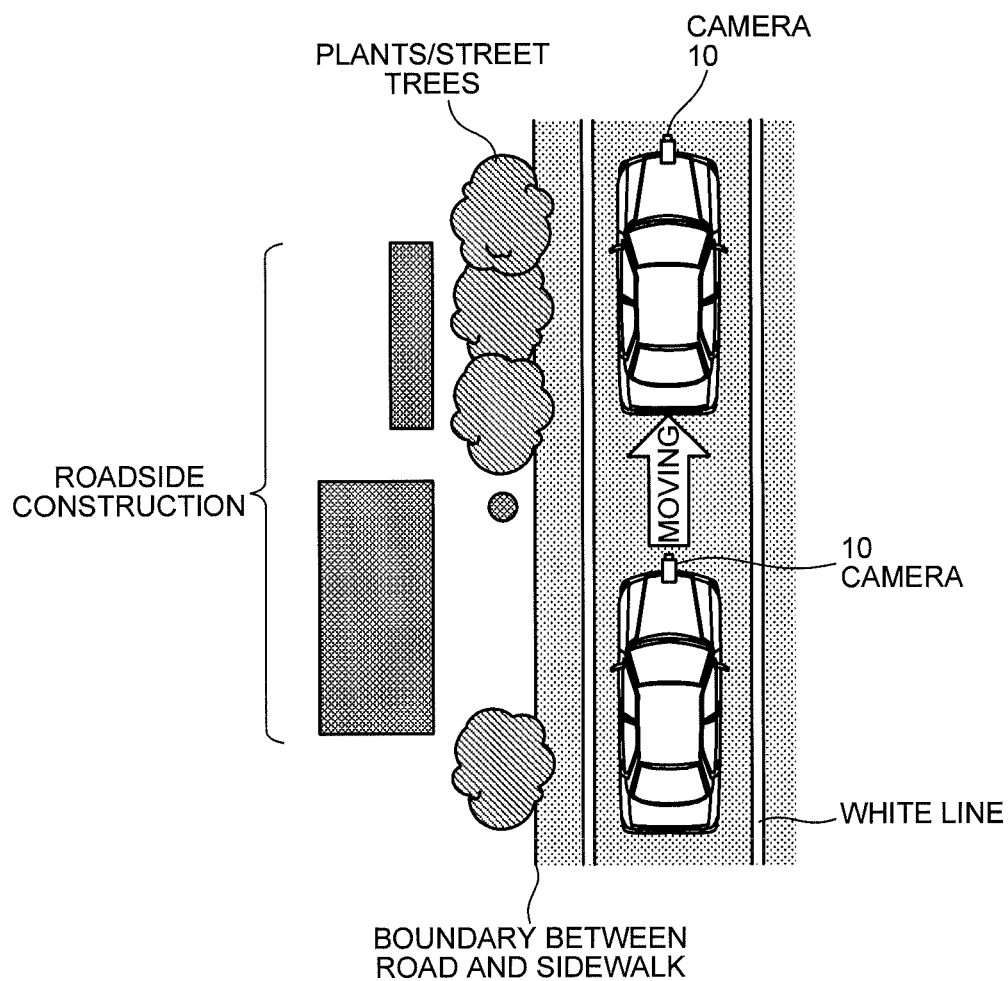


FIG. 7

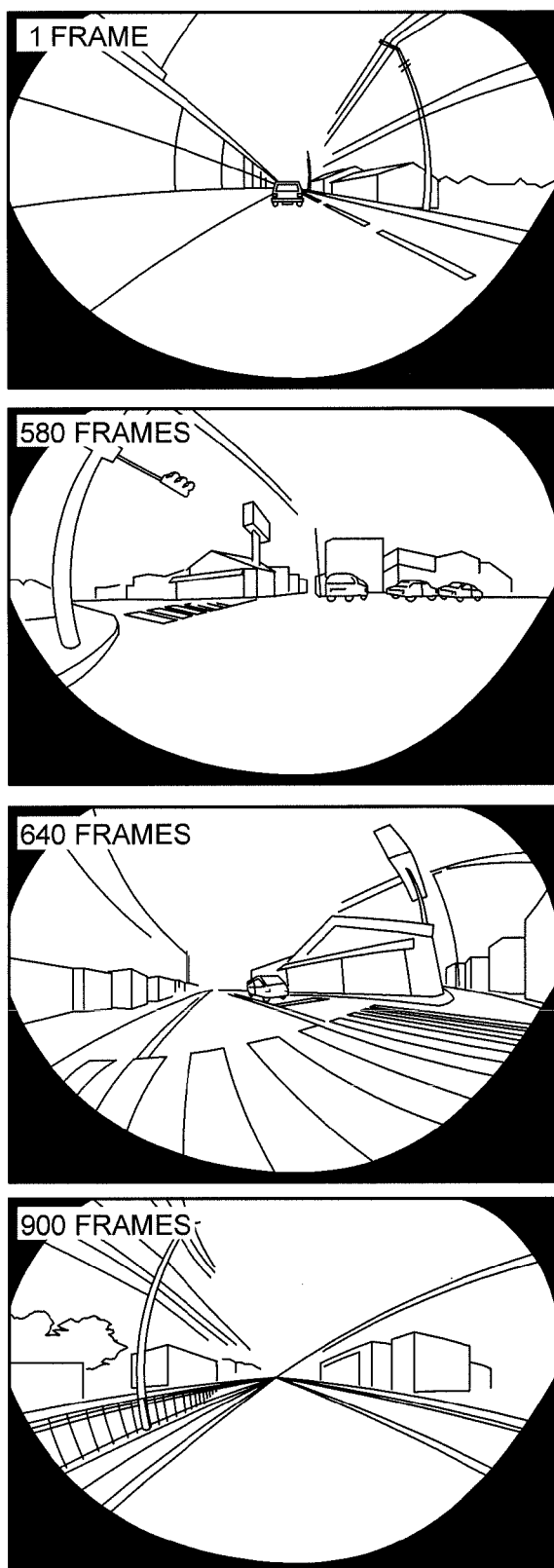




FIG. 8

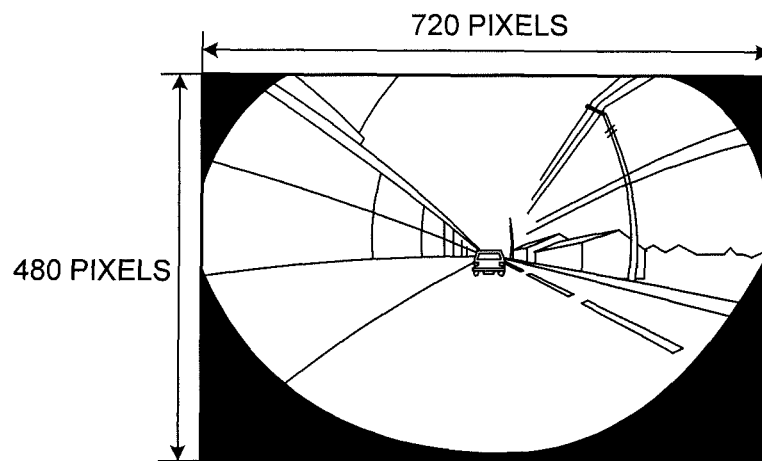


FIG. 9

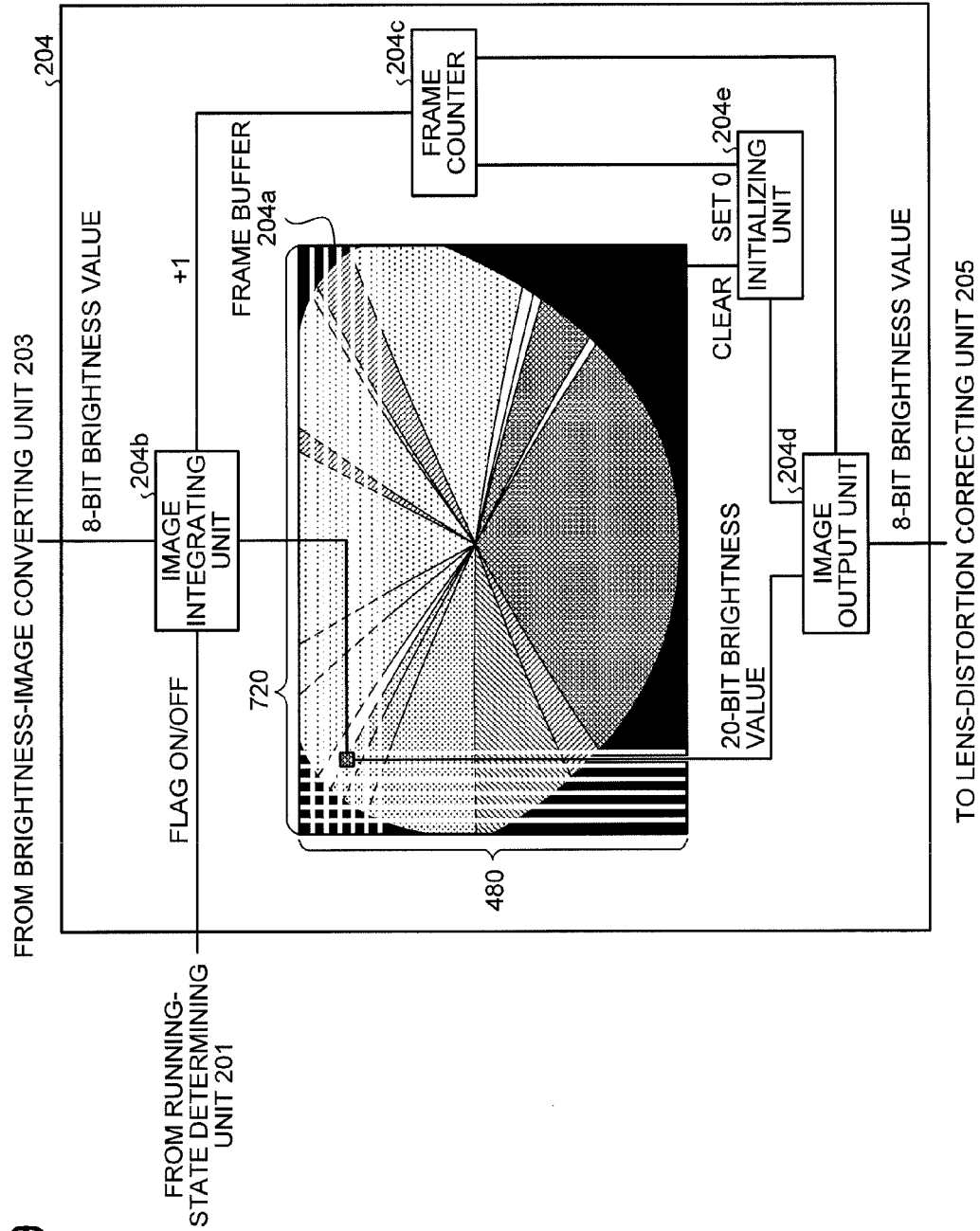


FIG. 10

CORRECTION TABLE

	POST-CORRECTION		PRE-CORRECTION	
	X	Y	X	Y
1	0	0	10	2
2	1	0	11	3
⋮	⋮	⋮	⋮	⋮

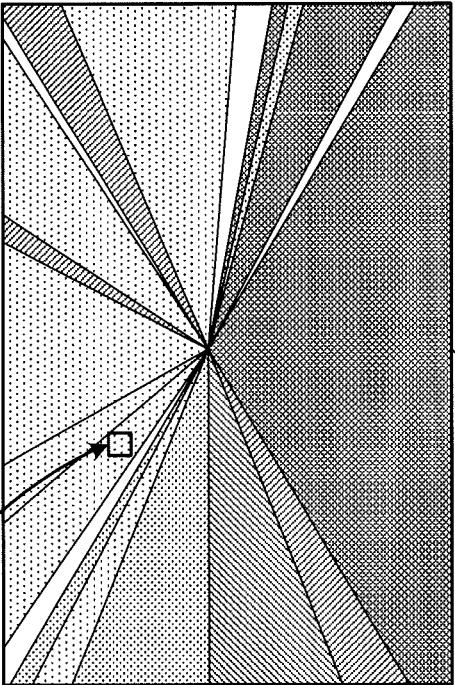
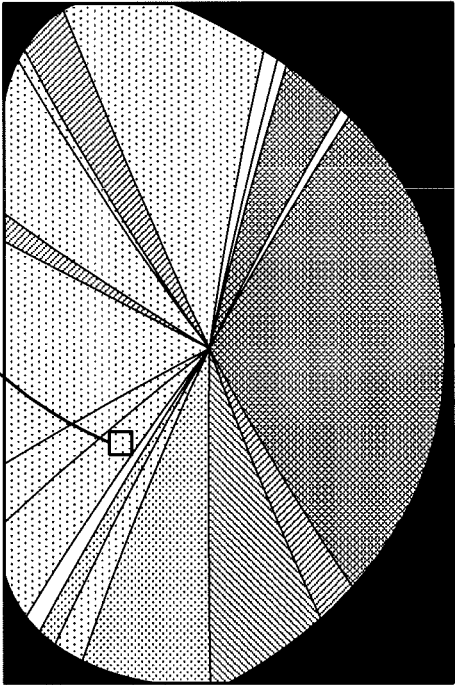


FIG. 11

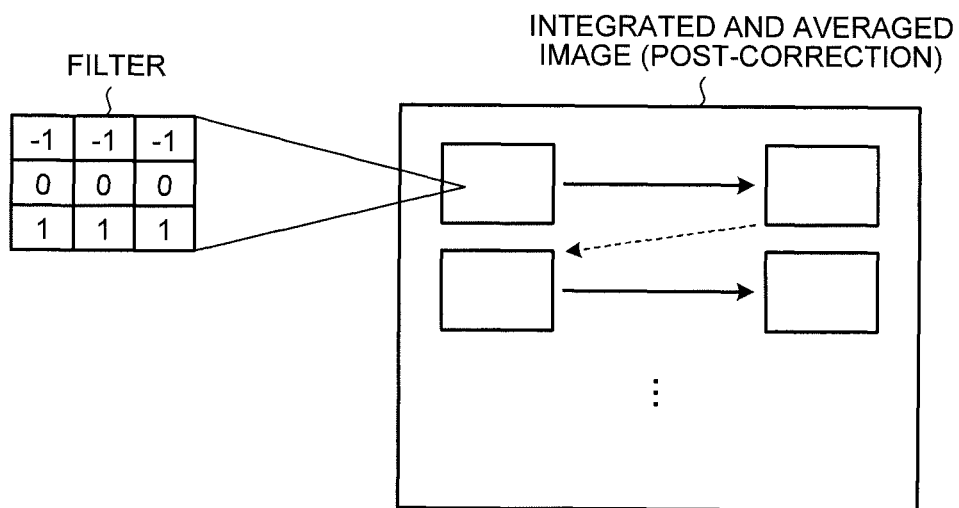


FIG. 12

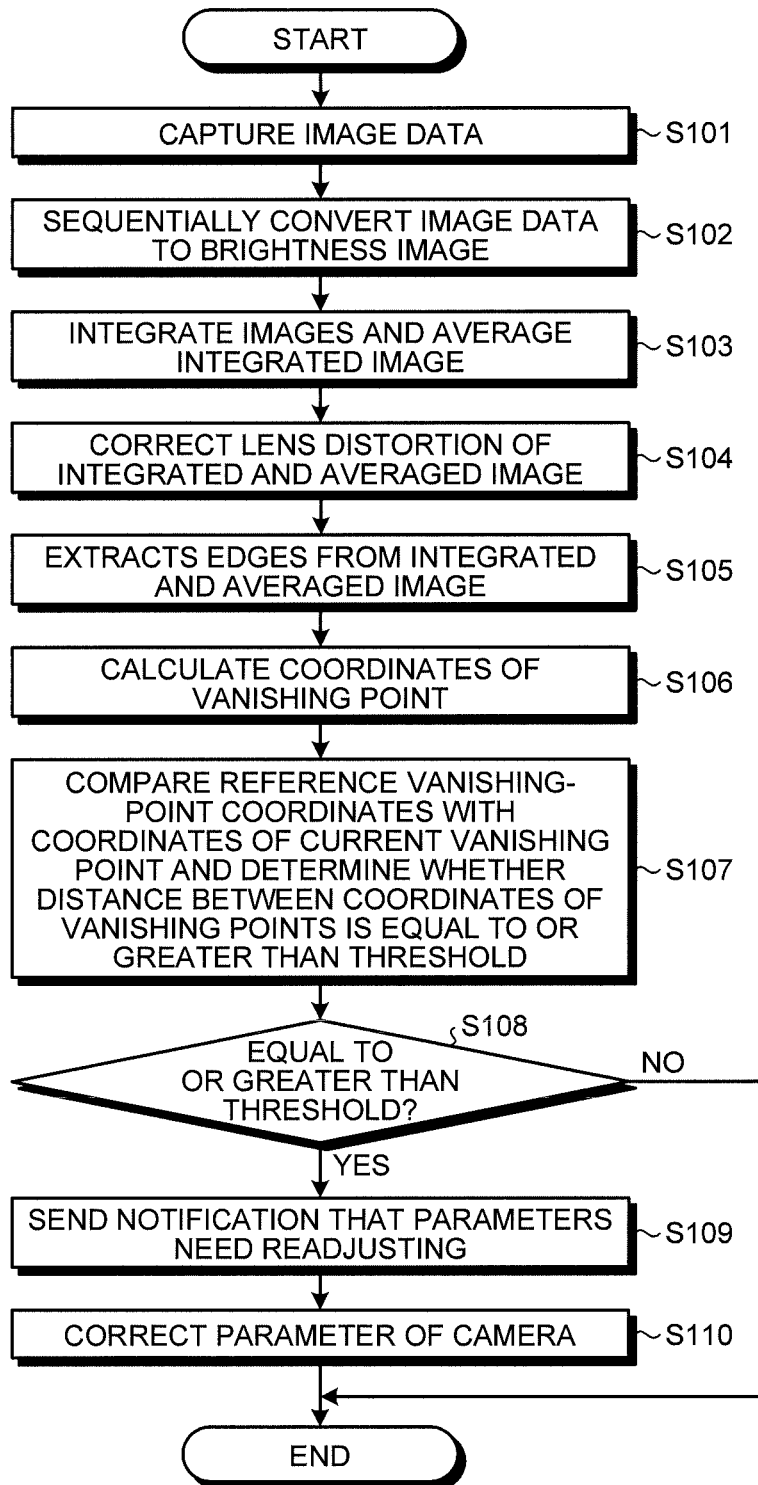


FIG.13

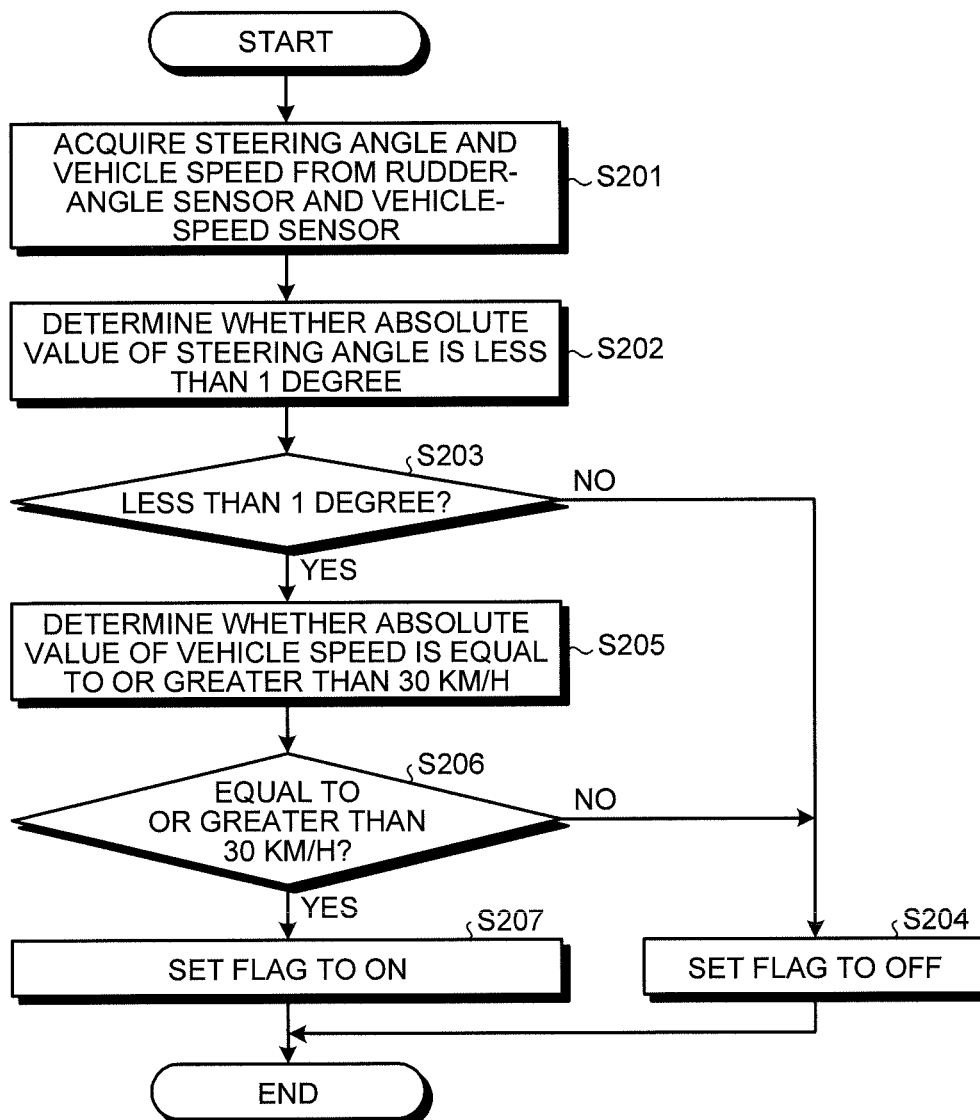
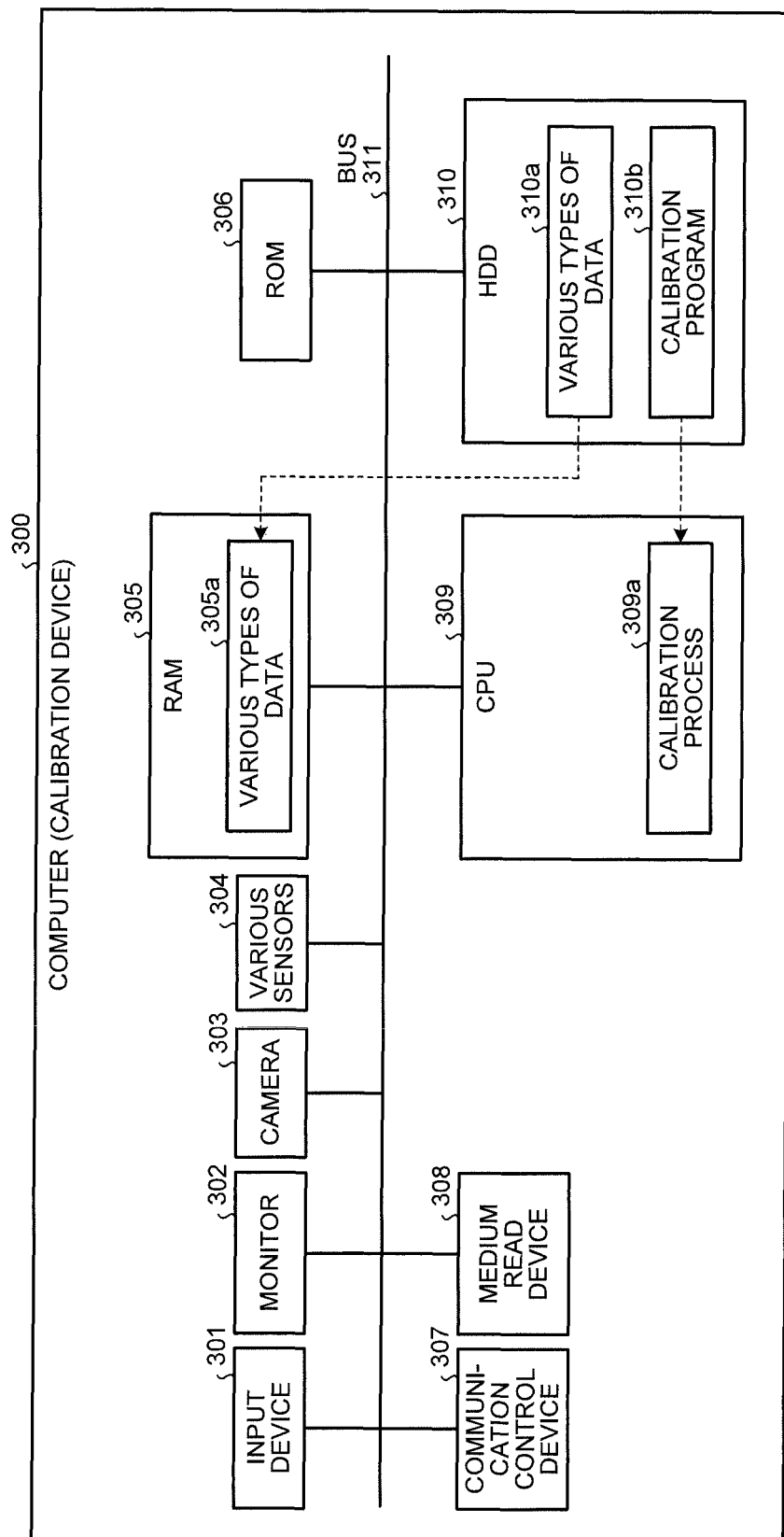


FIG. 14



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# IMAGE PROCESSING DEVICE AND IMAGE PROCESSING METHOD FOR CAMERA CALIBRATION

## CROSS-REFERENCE TO RELATED APPLICATION

This application is a continuation of International Appli-  
cation No. PCT/JP2009/061127, filed on Jun. 18, 2009, the  
entire contents of which are incorporated herein by reference.

## FIELD

The embodiments discussed herein are directed to an  
image processing device, or the like, that processes images.

## BACKGROUND

A technology has spread in recent years that uses images  
captured by a plurality of cameras installed on the circumfer-  
ence of a movable body and that displays an overhead (bird's  
eye) view that includes the image of the movable body taken  
from above or displays a 360-degree panoramic image by  
combining images. To convert the image captured by the  
camera into an overhead view, or the like, or to display a  
panoramic image by combining images, the parameters that  
are used include the positions (coordinates x, y, and z) of the  
camera, the angles (the depression angle  $\psi$ , the rotation angle  
 $\phi$ , and the pan angle  $\theta$ ) of the camera, and the like.

To install a camera on a movable body, because each  
parameter of the camera is different depending on the instal-  
lation condition and because of installation errors, calibration  
needs to be performed in order to correctly determine each  
parameter of the camera. The camera, which is installed on  
the movable body, is calibrated by using a special jig before  
shipment. However, the parameters of the camera gradually  
change due to degradation with aging after shipment and due  
to degradation of the area where the camera is installed.

For example, a change in the angle of the camera changes  
the result of calculating the distance between the camera and  
an object that is extracted from the image, which results in the  
incorrect displaying of an overhead image or panoramic  
image. Therefore, it is desirable to calibrate the camera after  
shipment. Because it is difficult to use a special jig after  
shipment, it is preferable to calibrate the camera without  
using a special jig.

A disclosed technology for performing calibration after  
shipment involves extracting the right and left white lines of  
the straight road along which the movable body is moving and  
calibrating the camera by using the extracted white lines.  
Another well-known technology involves calibrating the  
camera by using the geometric shape of a sign painted on the  
road surface.

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Japanese Laid-open Patent Publication No. 2001-225709

Japanese Laid-open Patent Publication No. 2008-11174

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Japanese Laid-open Patent Publication No. 2004-205398

The above-described conventional technology is based on  
the assumption that the road surface is flat in the image  
captured by the camera and that the white line or the painted  
sign satisfies an assumed shape. If these assumptions are not  
satisfied, there is a problem in that the conventional technol-  
ogy is not used.

Even if the white line or the painted sign satisfies the  
assumed shape, the conventional technology is not also used  
when the white line or the painted sign is concealed by a

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different vehicle. In an actual traffic environment, a situation  
often occurs where the white line or the painted sign is dis-  
torted or is concealed by a different vehicle.

Therefore, there are many situations where calibration is  
not performed even if a parameter of the camera is incorrect;  
thus, calibration is not correctly performed.

## SUMMARY

According to an aspect of an embodiment of the invention,  
an image processing device includes an integrating unit that  
acquires, from a camera installed on a movable body, images  
that are captured by the camera while the movable body is  
moving and integrates the acquired images so as to generate  
an integrated image; a vanishing-point identifying unit that  
extracts brightness edges from the integrated image and iden-  
tifies an intersection point of lines determined by using the  
brightness edges as a vanishing point; and a determining unit  
that determines whether a parameter of the camera has an  
appropriate value by using the coordinates of the vanishing  
point and reference coordinates.

The object and advantages of the embodiment will be  
realized and attained by means of the elements and combina-  
tions particularly pointed out in the claims.

It is to be understood that both the foregoing general  
description and the following detailed description are exem-  
plary and explanatory and are not restrictive of the embodi-  
ment, as claimed.

## BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 is a diagram that illustrates the configuration of an  
image processing device according to a first embodiment;

FIG. 2 is a diagram that explains the parameters of the  
camera;

FIG. 3 is a diagram that illustrates the configuration of a  
calibration device according to a second embodiment;

FIG. 4 is a diagram (1) that explains the outline of a process  
performed by the calibration device;

FIG. 5 is a diagram (2) that explains the outline of a process  
performed by the calibration device;

FIG. 6 is a diagram that illustrates a vehicle that is moving  
in a straight line;

FIG. 7 is a diagram that illustrates an example of the picture  
captured by the camera;

FIG. 8 is a diagram that illustrates an example of a bright-  
ness image of 720×480 pixels;

FIG. 9 is a diagram that illustrates the configuration of an  
image-integration averaging processing unit;

FIG. 10 is a diagram that illustrates a process performed by  
a lens-distortion correcting unit;

FIG. 11 is a diagram that explains a process performed by  
an edge extracting unit;

FIG. 12 is a flowchart that illustrates the steps of a process  
performed by the calibration device;

FIG. 13 is a flowchart that illustrates the steps of a process  
performed by a running-state determining unit; and

FIG. 14 is a diagram that illustrates the hardware configu-  
ration of a computer that includes the calibration device  
according to the embodiment.

## DESCRIPTION OF EMBODIMENTS

Preferred embodiments of the present invention will be  
explained with reference to accompanying drawings. The  
present invention is not limited to those embodiments.



## [a] First Embodiment

FIG. 1 is a diagram that illustrates the configuration of an image processing device according to a first embodiment. As illustrated in FIG. 1, an image processing device 100 includes a camera 10, an integrating unit 110, a vanishing-point identifying unit 120, and a determining unit 130.

The integrating unit 110 is a processing unit that acquires, from the camera 10 installed in a movable body, images that are captured while the movable body is moving and that integrates the acquired images so as to generate an integrated image.

The vanishing-point identifying unit 120 is a processing unit that extracts the brightness edges from the integrated image, determines lines by using the brightness edges, and identifies the intersection point of the lines as the vanishing point.

The determining unit 130 is a processing unit that determines whether a parameter of the camera has an appropriate value by using the coordinates of the vanishing point and the reference coordinates.

In the above-described image processing device 100, because the vanishing point is obtained from the integrated image, it can be determined, regardless of an actual traffic environment, whether calibration needs to be performed on the camera after shipment.

## [b] Second Embodiment

An explanation is first given of the parameters of the camera. FIG. 2 is a diagram that explains the parameters of the camera. As illustrated in FIG. 2, the parameters of the camera 10 include, with respect to the axes X, Y, and Z of the camera coordinate system with the origin at the camera 10, the depression angle  $\psi$ , which indicates the angle of rotation around the axis X of the camera, the rotation angle  $\phi$ , which indicates the angle of rotation around the axis Z, and the pan angle  $\theta$ , which indicates the angle of rotation around the axis Y. The axis Z corresponds to the optical axis of the camera 10.

Next, an explanation is given of the configuration of a calibration device according to a second embodiment. FIG. 3 is a diagram that illustrates the configuration of the calibration device according to the second embodiment. As illustrated in FIG. 3, a calibration device 200 includes the camera 10, a steering angle sensor 11, a vehicle-speed sensor 12, a running-state determining unit 201, an image processing unit 202, a brightness-image converting unit 203, an image-integration averaging processing unit 204, and a lens-distortion correcting unit 205. The calibration device 200 further includes an edge extracting unit 206, a vanishing-point extracting unit 207, a vanishing-point storage unit 208, an error determining unit 209, an HMI (Human Machine Interface) 210, a correction processing unit 211, and a camera-parameter storage unit 212. The calibration device 200 is installed, for example, within a vehicle.

Before each processing unit is explained in detail, the outline of a process performed by the calibration device 200 will be explained. FIGS. 4 and 5 are diagrams that illustrate the outline of a process performed by the calibration device.

As illustrated in FIG. 4, the calibration device 200 integrates the images captured by the camera 10 and averages the integrated image so as to generate an integrated and averaged brightness image. In the following explanation, the integrated and averaged brightness image is described as an integrated and averaged image (Step S10). For example, the calibration device 200 according to the second embodiment integrates the images of 1024 frames and then divides the brightness value of each pixel of the integrated image by 1024 so as to generate an integrated and averaged image.

The calibration device 200 takes into account the lens distortion of the camera 10 and performs the lens distortion correction on the integrated and averaged image (Step S11).

Next, an explanation is given with reference to FIG. 5. After the lens distortion correction has been performed, the calibration device 200 performs a filtering process on the integrated image so as to extract the edges from the integrated and averaged image (Step S12). In the following explanation, the integrated and averaged image from which the edges have been extracted is described as an edge image.

The calibration device 200 calculates, as a vanishing line, the straight line that connects the point sequence of the edges included in the edge image. Furthermore, the calibration device 200 calculates, as a vanishing point, the intersection point of the vanishing lines (Step S13). The calibration device 200 compares the calculated vanishing point with the reference vanishing point. If the distance between the two vanishing points is equal to or greater than a threshold, it is determined that calibration needs to be performed.

FIG. 6 is a diagram that illustrates a vehicle that is moving in a straight line. Because a motionless object captured by the camera 10 installed in the vehicle moves, relative to the vehicle, in the opposite direction of the movement of the vehicle, the motionless object describes a trajectory in a direction parallel to the movement direction in the image captured by the camera 10. Therefore, if an integrated and averaged image is generated from the images captured by the camera 10, the brightness gradient extending in a direction that does not match the moving direction of the vehicle is averaged, and only the brightness gradient extending in a direction parallel to the moving direction remains strong, as illustrated in FIG. 4.

As illustrated in FIG. 5, if the calibration device 200 performs filtering on the brightness gradient so as to determine the brightness edge, the brightness edge corresponds to the vanishing line that is generated due to the movement of the vehicle. The calibration device 200 calculates the intersection point of the vanishing lines so as to determine the vanishing point.

Next, an explanation is given of each processing unit illustrated in FIG. 3. The camera 10 captures pictures. The camera 10 outputs data on the captured pictures to the image processing unit 202 and the brightness-image converting unit 203. FIG. 7 is a diagram that illustrates an example of a picture captured by the camera.

The steering angle sensor 11 is a sensor that detects the steering angle of the vehicle. The steering angle sensor 11 outputs data on the steering angle to the running-state determining unit 201. The vehicle-speed sensor 12 is a sensor that detects the speed of the vehicle. The vehicle-speed sensor 12 outputs data on the vehicle speed to the running-state determining unit 201.

The running-state determining unit 201 is a processing unit that determines whether the current running state of the vehicle is appropriate for the calculation of the vanishing point by using the data on the steering angle and the vehicle speed. Specifically, the running-state determining unit 201 determines that the current running state of the vehicle is appropriate for the calculation of the vanishing point if the absolute value of the current steering angle is less than the reference steering angle (e.g., 1 degree) and if the absolute value of the current speed is equal to or greater than the reference speed (e.g., 30 km/h).

Conversely, if the absolute value of the current steering angle is equal to or greater than the reference steering angle or if the absolute value of the current speed is less than the reference speed, the running-state determining unit 201 deter-

mines that the current running state of the vehicle is not appropriate for the calculation of the vanishing point.

If it is determined that the current running state of the vehicle is appropriate for the calculation of the vanishing point, the running-state determining unit **201** sets a flag in the image-integration averaging processing unit **204** to on. If it is determined that the current running state of the vehicle is not appropriate for the calculation of the vanishing point, the running-state determining unit **201** sets a flag in the image-integration averaging processing unit **204** to off.

The image processing unit **202** is a processing unit that analyzes the picture output from the camera **10** in accordance with the camera parameters stored in the camera-parameter storage unit **212**. For example, the image processing unit **202** determines the coordinates of the white line in the image and, if the white line enters a predetermined area of the image, determines that the vehicle has deviated from the traffic lane and gives the user a warning. The image processing unit **202** may detect an obstacle included in the picture and output a crash warning to the user.

The brightness-image converting unit **203** is a processing unit that converts the picture output from the camera **10** into a brightness image of 720×480 pixels and outputs the converted brightness image to the image-integration averaging processing unit **204**. FIG. 8 is a diagram that illustrates an example of a brightness image of 720×480 pixels. Each pixel of the brightness image has 8-bit information (brightness value).

The image-integration averaging processing unit **204** is a processing unit that sequentially acquires a brightness image from the brightness-image converting unit **203** and integrates and averages each brightness image so as to generate an integrated and averaged image. The image-integration averaging processing unit **204** outputs the integrated and averaged image to the lens-distortion correcting unit **205**.

The image-integration averaging processing unit **204** integrates brightness images that are acquired from the brightness-image converting unit **203** while the flag is on. The image-integration averaging processing unit **204** does not integrate brightness images that are acquired from the brightness-image converting unit **203** while the flag is off. The image-integration averaging processing unit **204** discards such brightness images.

An explanation is given here of the configuration of the image-integration averaging processing unit **204**. FIG. 9 is a diagram that illustrates the configuration of the image-integration averaging processing unit **204**. As illustrated in FIG. 9, the image-integration averaging processing unit **204** includes a frame buffer **204a**, an image integrating unit **204b**, a frame counter **204c**, an image output unit **204d**, and an initializing unit **204e**.

The frame buffer **204a** is a two-dimensional memory that has 720×480 memory areas. Each memory area of the frame buffer **204a** stores 20-bit information.

The image integrating unit **204b** is a processing unit that repeats a process with the following steps: acquires a brightness image from the brightness-image converting unit **203**, adds each brightness value of the brightness image and each brightness value in the frame buffer **204a**, and returns the result of the addition to the corresponding memory area of the frame buffer **204a**.

Specifically, the image integrating unit **204b** acquires the 20-bit brightness value that is stored in the memory area in the n-th row and the m-th column (n=1 to 480, m=1 to 720) of the frame buffer **204a**. The image integrating unit **204b** adds the brightness value acquired from the frame buffer **204a** and the brightness value (8 bits) of the pixel in the n-th row and the

m-th column frame of the brightness image and stores the result of the addition in the memory area in the n-th row and the m-th column of the frame buffer **204a**.

The image integrating unit **204b** repeats the above-described addition process each time the image integrating unit **204b** acquires a brightness image from the brightness-image converting unit **203** while the flag in the image integrating unit **204b** is on. The image integrating unit **204b** adds one to the number of frames in the frame counter **204c** each time the image integrating unit **204b** performs the addition process. The vehicle is moving in a straight line while the flag in the image integrating unit **204b** is on.

When acquiring a brightness image from the brightness-image converting unit **203** while the flag in the image integrating unit **204b** is off, the image integrating unit **204b** does not perform the above-described addition process and discards the acquired brightness image. The vehicle is not moving in a straight line while the flag in the image integrating unit **204b** is off.

The frame counter **204c** is a storage unit that stores the number of integrated frames. The initial value of the frame number stored in the frame counter **204c** is set to zero.

The image output unit **204d** is a processing unit that, when the frame number in the frame counter **204c** becomes 1024, acquires the added value (20 bits) stored in each memory area of the frame buffer **204a** and divides each added value by 1024 (shifts to the right by 16 bits) so as to generate an integrated and averaged image. The image output unit **204d** outputs the integrated and averaged image to the lens-distortion correcting unit **205**. The image output unit **204d** outputs a control signal to the initializing unit **204e** after the integrated and averaged image is generated.

When obtaining the control signal from the image output unit **204d**, the initializing unit **204e** sets the information in each memory area of the frame buffer **204a** to zero and also sets the frame number in the frame counter **204c** to zero.

An explanation is given with reference to FIG. 3 again. The lens-distortion correcting unit **205** is a processing unit that corrects the lens distortion of an integrated and averaged image when acquiring the integrated and averaged image from the image-integration averaging processing unit **204**. The lens-distortion correcting unit **205** outputs to the edge extracting unit **206** the integrated and averaged image for which the lens distortion has been corrected.

The lens-distortion correcting unit **205** corrects the lens distortion of the integrated and averaged image so as to convert the projection of the integrated and averaged image into an ideal perspective projection.

Specifically, the lens-distortion correcting unit **205** has a conversion table and, by using the conversion table, corrects an integrated and averaged image. FIG. 10 is a diagram that illustrates a process performed by the lens-distortion correcting unit **205**. As illustrated in FIG. 10, the conversion table stores pre-correction coordinates and post-correction coordinates that are related to one another. For example, the pre-correction coordinates x, y in the first line of the conversion table are (10, 2), and the post-correction coordinates x, y are (0, 0).

The lens-distortion correcting unit **205** refers to the first line of the conversion table and shifts the brightness value on the coordinates (10, 2) of the integrated and averaged image to the coordinates (0, 0). The lens-distortion correcting unit **205** also refers to the other lines and shifts the brightness value of the integrated and averaged image to different coordinates so as to correct the integrated and averaged image.

Instead of using the conversion table, the lens-distortion correcting unit **205** may sequentially correct an integrated

and averaged image by using lens distortion data that includes the incidence angle and the image height.

The edge extracting unit **206** is a processing unit that acquires from the lens-distortion correcting unit **205** the integrated and averaged image, on which the correction has been performed, and performs a filtering process on the integrated and averaged image so as to generate an edge image that is obtained by extracting the edges from the integrated and averaged image. The edge extracting unit **206** outputs the edge image to the vanishing-point extracting unit **207**.

FIG. **11** is a diagram that explains a process performed by the edge extracting unit **206**. The edge extracting unit **206** applies a filter to the integrated and averaged image, multiplies each value of the filter by the corresponding brightness value of the integrated and averaged image, and adds each multiplication result. If the result obtained by adding the multiplication results exceeds a certain threshold (e.g., 100), the edge extracting unit **206** sets the brightness value corresponding to the central block of the filter to 128. Conversely, if the result obtained by adding the multiplication results is equal to or less than a certain threshold (e.g., -100), the edge extracting unit **206** sets the brightness value corresponding to the central block of the filter to -128. If the result obtained by adding the multiplication result does not satisfy any one of the conditions, the brightness value corresponding to the central block of the filter is set to 0.

For example, in the area of the integrated and averaged image with which the filter is overlapped, if the brightness value in the a-th row and the b-th column is  $B_{ab}$  and if the result obtained by adding the multiplication results is A, the result A is obtained as follows:  $A = -1 \times B_{11} + -1 \times B_{12} + -1 \times B_{13} + 0 \times B_{21} + 0 \times B_{22} + 0 \times B_{23} + 1 \times B_{31} + 1 \times B_{32} + 1 \times B_{33}$ .

If A is plus, for example, equal to or greater than 100, the edge extracting unit **206** sets the brightness value corresponding to  $B_{22}$  to 128. If A is minus, for example, equal to or less than -100, the edge extracting unit **206** sets the brightness value corresponding to  $B_{22}$  to -128. Otherwise, the edge extracting unit **206** sets the brightness value to 0.

The edge extracting unit **206** moves the filter on the integrated and averaged image and sequentially sets the brightness value of the integrated and averaged image so as to generate an edge image.

An explanation is given here with reference to FIG. **3** again. The vanishing-point extracting unit **207** is a processing unit that acquires an edge image from the edge extracting unit **206** and calculates the coordinates of the vanishing point by using the edge image. The vanishing-point extracting unit **207** connects the sequence of points with the brightness value of 128 included in the edge image by using a straight line so as to calculate a vanishing line. Furthermore, the vanishing-point extracting unit **207** connects the sequence of points with the brightness value of -128 included in the edge image by using a straight line so as to calculate a vanishing line. The vanishing-point extracting unit **207** may use the well-known Hough transform to calculate the vanishing line from the sequence of points.

After calculating the vanishing line, the vanishing-point extracting unit **207** obtains the intersection point of the vanishing lines and determines the coordinates of the obtained intersection point as the coordinates of the vanishing point. The vanishing-point extracting unit **207** outputs the coordinates of the vanishing point to the error determining unit **209**. The vanishing-point extracting unit **207** also outputs information on the vanishing lines to the error determining unit **209**.

The vanishing-point storage unit **208** is a storage unit that stores therein the coordinates of a reference vanishing point.

In the following explanation, the coordinates of the reference vanishing point are described as reference vanishing-point coordinates.

The error determining unit **209** is a processing unit that compares the coordinates of the vanishing point acquired from the vanishing-point extracting unit **207** with the reference vanishing-point coordinates and that determines whether any parameters of the camera **10** are to be readjusted. If the distance between the reference vanishing-point coordinates and the coordinates of the vanishing point acquired from the vanishing-point extracting unit **207** is equal to or greater than a threshold, the error determining unit **209** determines that a parameter needs to be readjusted. If it is determined that a parameter needs to be readjusted, the error determining unit **209** outputs to the HMI **210** and the correction processing unit **211** information that indicates that a parameter needs to be readjusted. Furthermore, the error determining unit **209** outputs the coordinates of the vanishing point to the correction processing unit **211**.

The HMI **210** is a processing unit that, when acquiring from the error determining unit **209** the information that indicates that a parameter needs to be readjusted, displays the information that indicates that a parameter needs to be readjusted on a display (not illustrated) via the image processing unit **202**.

The correction processing unit **211** is a processing unit that corrects a parameter stored in the camera-parameter storage unit **212** when acquiring from the error determining unit **209** the information that indicates that a parameter needs to be readjusted.

The correction processing unit **211** calculates the deviation of the coordinates of the vanishing point acquired from the error determining unit **209** from the reference vanishing-point coordinates stored in the vanishing-point storage unit **208** and corrects the parameters in accordance with the calculated deviation. Specifically, the correction processing unit **211** calculates the axis-X deviation  $X_s$  and the axis-Y deviation  $Y_s$  of the coordinates of the vanishing point from the reference vanishing-point coordinates in the XY coordinate system (the axis X is the horizontal direction of the image, and the axis Y is the vertical direction of the image).

For example, the correction processing unit **211** calculates the deviation angles  $\Delta\psi$ ,  $\Delta\theta$  by using  $\Delta\psi = \tan^{-1}(X_s/L_x)$  and  $\Delta\theta = \tan^{-1}(Y_s/L_y)$ .  $L_x$  and  $L_y$  are the focal lengths of the camera **10**.

The correction processing unit **211** corrects the parameters by adding  $\Delta\psi$  to the depression angle  $\psi$ , which is a parameter stored in the camera-parameter storage unit **212**, and adding  $\Delta\theta$  to the pan angle  $\theta$ . After the correction of the parameters has been completed, the correction processing unit **211** stores in the vanishing-point storage unit **208** the coordinates of the vanishing point acquired from the error determining unit **209** as reference vanishing-point coordinates. The correction processing unit **211** discards the previous reference vanishing-point coordinates stored in the vanishing-point storage unit **208**.

The camera-parameter storage unit **212** is a storage unit that stores the parameters of the camera **10**. The camera-parameter storage unit **212** may store therein the three-dimensional coordinates (x, y, z) of the camera **10** in addition to the above-described parameters.

Next, an explanation is given of the steps of a process performed by the calibration device **200** according to the second embodiment. FIG. **12** is a flowchart that illustrates the steps of the process performed by the calibration device **200**. As illustrated in FIG. **12**, the calibration device **200** acquires

image data from the camera **10** (Step **S101**) and sequentially converts the image data into a brightness image (Step **S102**).

The calibration device **200** integrates the images and averages the integrated image (Step **S103**). The calibration device **200** corrects the lens distortion of the integrated and averaged image (Step **S104**). The calibration device **200** extracts the edges from the integrated and averaged image (Step **S105**) and calculates the coordinates of the vanishing point (Step **S106**).

The calibration device **200** compares the reference vanishing-point coordinates with the coordinates of the current vanishing point and determines whether the distance between the coordinates of the vanishing points is equal to or greater than a threshold (Step **S107**). If the distance between the coordinates of the vanishing points is less than the threshold (No at Step **S108**), the calibration device **200** terminates the process.

Conversely, if the distance between the coordinates of the vanishing points is equal to or greater than the threshold (Yes at Step **S108**), the calibration device **200** sends a notification that the parameters of the camera need to be readjusted (Step **S109**) and corrects the parameters of the camera (Step **S110**).

Next, an explanation is given of the steps of a process performed by the running-state determining unit **201** illustrated in FIG. 3. FIG. 13 is a flowchart that illustrates the steps of a process performed by the running-state determining unit **201**. As illustrated in FIG. 13, the running-state determining unit **201** acquires the steering angle and the vehicle speed from the steering angle sensor **11** and the vehicle-speed sensor, respectively (Step **S201**), and determines whether the absolute value of the steering angle is less than 1 degree (Step **S202**).

If the absolute value of the steering angle is equal to or greater than 1 degree (No at Step **S203**), the running-state determining unit **201** sets the flag in the image-integration averaging processing unit **204** to off (Step **S204**). If the absolute value of the steering angle is less than 1 degree (Yes at Step **S203**), the running-state determining unit **201** determines whether the absolute value of the vehicle speed is equal to or greater than 30 km/h (Step **S205**).

If the running-state determining unit **201** determines that the absolute value of the vehicle speed is less than 30 km/h (No at Step **S206**), the process proceeds to Step **S204**. Conversely, if it is determined that the absolute value of the vehicle speed is equal to or greater than 30 km/h (Yes at Step **S206**), the running-state determining unit **201** sets the flag to on (Step **S207**).

As described above, the calibration device **200** according to the second embodiment integrates/averages an image that is acquired while the vehicle is moving so as to identify the vanishing lines, whereby the vanishing lines of movement can be calculated even in a situation where there is no flat road surface or parallel roadside lines (white lines). Thus, without regard to an actual traffic environment, calibration can be correctly performed after shipment. That is, the parameters of the camera can be accurately corrected without regard to the traffic environment.

Furthermore, the calibration device **200** according to the second embodiment interrupts the integration of images in accordance with the steering angle and the vehicle speed output from the steering angle sensor **11** and the vehicle-speed sensor **12**, respectively. Thus, it is possible to prevent the integration of pictures that describe lines that cause misalignment of the vanishing point.

#### [c] Third Embodiment

An explanation is given so far of the embodiments of the present invention; however, the present invention may be embodied in various different forms other than the first and

second embodiments. A different embodiment of the present invention is explained below as a third embodiment.

#### (1) Determination of Running State

In the second embodiment, the running-state determining unit **201** uses the steering angle sensor **11** and the vehicle-speed sensor **12** to determine whether the vehicle is moving in a straight line; however, the present invention is not limited to this. The running-state determining unit **201** may use other sensors, such as an acceleration sensor or gyroscope to determine the running state of the vehicle.

#### (2) Configuration of System, and the Like

Among the processes described in the embodiments, all or some of the processes that are automatically performed as described above can be performed manually. All or some of the processes that are manually performed as described above can be performed automatically by using a well-known method. Furthermore, the procedures, the control procedures, the specific names, and the information including various types of data and parameters as described in the specifications and the drawings can be arbitrarily changed except as otherwise noted.

Each of the components of the devices depicted in the drawings is based on a functional concept and does not necessarily need to be physically configured as depicted in the drawings. Specific forms of separation and integration of each device are not limited to the ones depicted in the drawings. It is possible that all or some of them are functionally or physically separated or integrated in an arbitrary unit depending on various types of loads or usage.

For example, a configuration may be such that a server has functions corresponding to the brightness-image converting unit **203**, the image-integration averaging processing unit **204**, the lens-distortion correcting unit **205**, the edge extracting unit **206**, the vanishing-point extracting unit **207**, the error determining unit **209**, the vanishing-point storage unit **208**, and the correction processing unit **211**, which are illustrated in FIG. 3, and the images captured by the camera or various types of data including the parameters are transmitted to the server so that the server corrects the parameters.

All or any of the processing functions performed by each of the devices can be implemented by a CPU and programs analyzed and executed by the CPU or implemented as wired logic hardware.

FIG. 14 is a diagram that illustrates the hardware configuration of a computer that includes the calibration device **200** according to the embodiment. As illustrated in FIG. 14, a computer (calibration device) **300** includes an input device **301**, a monitor **302**, a camera **303**, various sensors **304**, such as a steering angle sensor or a vehicle-speed sensor, and a Random Access Memory (RAM) **305**. The computer **300** further includes a Read Only Memory (ROM) **306**, a communication control device **307** that communicates with a different device, a medium read device **308** that reads data from a storage medium, a Central Processing Unit (CPU) **309**, and a Hard Disk Drive (HDD) **310**. Each of the devices **301** to **310** is connected to a bus **311**.

The HDD **310** stores therein a calibration program **310b** that performs the same function as that of the above-described calibration device **200**. The CPU **309** reads and executes the calibration program **310b** so that a calibration process **309a** is started. Here, the calibration process **309a** corresponds to the running-state determining unit **201**, the image processing unit **202**, the brightness-image converting unit **203**, the image-integration averaging processing unit **204**, the lens-distortion correcting unit **205**, the edge extracting unit **206**, the vanish-

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ing-point extracting unit 207, the error determining unit 209, the HMI 210, and the correction processing unit 211, which are illustrated in FIG. 3.

The HDD 310 stores various types of data 310a that correspond to the information stored in the vanishing-point storage unit 208 and the camera-parameter storage unit 212. The CPU 309 reads the data 310a stored in the HDD 310, stores the data 310a in the RAM 305, and corrects the parameters by using the data 305a stored in the RAM 305, the images captured by the camera 303, and the information sent from various sensors 304.

The calibration program 310b illustrated in FIG. 14 does not need to be stored initially in the HDD 310. For example, the calibration program 310b may be stored in a “portable physical medium”, such as a flexible disk (FD), a CD-ROM, a DVD disk, a magneto-optical disk, or an IC card, that is inserted into the computer. The calibration program 310b may be stored in a “fixed physical medium”, such as a hard disk drive (HDD), that is arranged inside or outside the computer. Moreover, the calibration program 310b may be stored in “another computer (or server)”, or the like, that is connected to the computer via, for example, a public line, the Internet, a LAN, a WAN, or the like. The computer may read the calibration program 310b from it and execute the program.

Without regard to an actual traffic environment, an image processing device according to the present invention can correctly determine when calibration is to be performed after shipment.

All examples and conditional language recited herein are intended for pedagogical purposes to aid the reader in understanding the invention and the concepts contributed by the inventor to furthering the art, and are to be construed as being without limitation to such specifically recited examples and conditions, nor does the organization of such examples in the specification relate to a showing of the superiority and inferiority of the invention. Although the embodiments of the present invention have been described in detail, it should be understood that the various changes, substitutions, and alterations could be made hereto without departing from the spirit and scope of the invention.

What is claimed is:

1. An image processing device comprising:
  - an integrating unit configured to acquire, from a camera installed on a movable body, images that are captured by the camera while the movable body is moving and integrates the acquired images so as to generate an integrated image;
  - a vanishing-point identifying unit configured to extract brightness edges from the integrated image and identifies an intersection point of lines determined by using the brightness edges as a vanishing point;
  - a determining unit configured to determine whether a parameter of the camera has an appropriate value by using coordinates of the vanishing point identified and reference coordinates, the reference coordinates being coordinates of a reference vanishing point stored; and
  - a correcting unit configured to correct the parameter of the camera in accordance with a difference between the coordinates of the vanishing point identified and the reference coordinates.
2. The image processing device according to claim 1, wherein the integrating unit is configured to acquire a moving speed of the movable body from a speed sensor and, while the acquired moving speed is equal to or greater than a predeter-

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mined speed, integrates images obtained from the camera so as to generate the integrated image.

3. The image processing device according to claim 2, wherein the integrating unit is configured to acquire a steering angle of the movable body from a steering angle sensor and, while the acquired steering angle is less than a predetermined steering angle, integrates images obtained from the camera so as to generate the integrated image.

4. The image processing device according to claim 1, wherein the integrating unit is configured to acquire the integrated image by adding and averaging the brightness value of the acquired images for each pixel.

5. The image processing device according to claim 1, wherein the parameter of the camera includes a pan angle or a depression angle.

6. An image processing method performed by an image processing device, the image processing method comprising: acquiring, from a camera installed on a movable body, images that are captured by the camera while the movable body is moving and integrating the acquired images so as to generate an integrated image;

extracting brightness edges from the integrated image and identifying an intersection point of lines determined by using the brightness edges as a vanishing point;

determining whether a parameter of the camera has an appropriate value by using the coordinates of the vanishing point identified and reference coordinates, the reference coordinates being coordinates of a reference vanishing point stored; and

correcting the parameter of the camera in accordance with a difference between the coordinates of the vanishing point identified and the reference coordinates.

7. The image processing method according to claim 6, the integrating includes acquiring a moving speed of the movable body from a speed sensor and, while the acquired moving speed is equal to or greater than a predetermined speed, integrating images obtained from the camera so as to generate the integrated image.

8. The image processing method according to claim 7, the integrating includes acquiring a steering angle of the movable body from a steering angle sensor and, while the acquired steering angle is less than a predetermined steering angle, integrating images obtained from the camera so as to generate the integrated image.

9. An image processing device comprising:

a processor; and

a memory which stores a plurality of instructions, which when executed by the processor, cause the processor to execute:

acquiring, from a camera installed on a movable body, images that are captured by the camera while the movable body is moving and integrating the acquired images so as to generate an integrated image;

extracting brightness edges from the integrated image and identifying an intersection point of lines determined by using the brightness edges as a vanishing point;

determining whether a parameter of the camera has an appropriate value by using the coordinates of the vanishing point identified and reference coordinates, the reference coordinates being coordinates of a reference vanishing point stored; and

correcting the parameter of the camera in accordance with a difference between the coordinates of the vanishing point identified and the reference coordinates.

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